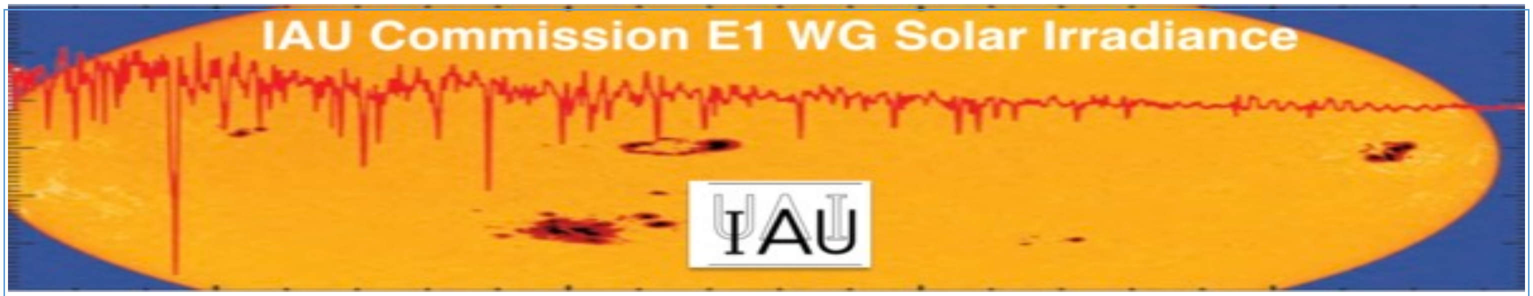

Solar Irradiance Working Group Newsletter, Vol. 2, Dec. 2016

WG Proposal Submitted for IAU GA XXX 2018

Thank you all for your inputs on our working group's proposal for a Focus Meeting at the IAU General Assembly XXX in Vienna in 2018. The proposed meeting, containing four sessions spread over two days, will link recent physics-based improvements to models of radiative transfer, surface-flux transport, and 3-D magnetohydrodynamics to studies of solar-irradiance variability, drawing on new understandings provided by long-term stellar-variability observations and modeling. Our working group's "Solar Irradiance: Physics-Based Advances" proposal was submitted on 15 Dec. and is reprinted below. We appreciated the inputs from all of you on this proposal effort and will be eager to get your help when (not "if") we are selected, as you are also a member of the proposed Focus Meeting's SOC and so will be instrumental in finalizing the meeting agenda based on the proposed outline (given below).

Website and E-Mail List

We have set up a website for our WG. Please send either of us any changes you suggest or new, relevant publications that should be added. Additionally, an e-mail list, of which you are already a member, will allow us all to share issues relevant to our working group.

Solar Irradiance: Physics-Based Advances

Proposed Meeting Details

Category:	Focus Meeting
GA meeting:	yes
Title:	Solar Irradiance: Physics-Based Advances
Start date:	2018-08-21
End date:	2018-08-22
Location:	Vienna
Country:	Austria
Coordinating division:	Division E Sun and Heliosphere
Other divisions:	Division B Facilities, Technologies and Data Science Division G Stars and Stellar Physics

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Editor(s) of Proceedings

Greg Kopp, Laboratory for Atmospheric and Space Physics, Univ. of Colorado

Alexander Shapiro, Max-Planck-Institut für Sonnensystemforschung

Scientific Justification

Key Topics

1. Overview of existing solar-irradiance datasets (models and observations)
2. Proxies of long-term solar magnetic activity
3. State-of-the-art in solar-irradiance modeling
4. Simulations of solar surface magnetic field distribution with surface flux transport models
5. Structure of solar magnetic features: What can we learn from MHD simulations?
6. Radiative transfer calculations for next generation of irradiance models
7. Brightness contrasts of solar magnetic features from high-resolution solar imagery (SUNRISE, SDO, HINODE, etc.)
8. Solar-irradiance variability on timescales less than a day: magnetic and non-magnetic components
9. Can we use solar models to explain brightness variations of Sun-like stars?
10. Climate research needs for solar-irradiance time series: temporal and spectral coverage, critical issues, and priorities

Abstract

Understanding and modeling of solar-irradiance variability is important not only for solar physics but also for solar-stellar and solar-terrestrial studies. Recent controversies and debates showed that currently available empirical and semi-empirical models of solar-irradiance variability fail to answer a number of critical questions prompted by the latest irradiance measurements. At the same time, recent advances in modeling and observing the solar atmosphere make it possible to create a new generation of significantly more realistic physics-based irradiance models. Without relying on empirical relationships established for the Sun, they will also allow more direct and physical extrapolations to other stars, opening a new regime for solar-stellar connection studies. Development of this next generation of irradiance models, taking into account the new rapid advances in MHD, surface flux transport, and radiative transfer simulations as well as new state-of-the-art solar da ta, requires active communication and collaboration. The IAU General Assemblies are the only meetings which are broadly attended by all needed, diverse communities. Thus, we propose a 2-day, 4-session Focus Meeting at IAU GA XXX to bring the relevant researchers together and initiate joint projects and collaborations. This Focus Meeting has the support of three IAU Divisions plus eight Commissions or Working Groups.

Scientific Rationale

Solar irradiance varies on all timescales over which it has been observed and is believed to also vary over much longer ones having direct influences on Earth climate. Irradiance variability on timescales longer than a day is attributed to solar surface magnetic field changes. On shorter timescales the magnetic-caused irradiance variability is complemented by the constantly-evolving spatially-averaged superposition of granulation and solar oscillations.

Interest in solar-irradiance variability extends well beyond the solar community. The terrestrial atmospheric and climate systems respond to variations in solar radiative output on timescales from days to decades, and there is also evidence for solar-driven climate influences over longer timescales. The variability of solar irradiance is also of interest to stellar astronomers, who have been comparing it with the variability of other lower main sequence stars. Understanding the physics behind solar variability helps assess stellar brightness variations (and vice-versa) and the resulting effects on the detectability and habitability of exoplanets.

Early models of solar-irradiance variability were purely empirical. These were primarily based on observed correlations between measured solar irradiance and solar magnetic activity proxies. Successive generations of models utilized semi-empirical 1D models of solar magnetic features and surrounding quiet regions. The brightness contrasts of magnetic features have been calculated with simplified radiative transfer methods, e.g. often ignoring effects of non-local thermodynamic equilibrium. These semi-empirical models provided insights into the causes of irradiance variability and enabled some understanding of the physics behind the empirical correlations.

While the semi-empirical approach has been at the forefront of irradiance models for many years, it is largely based on foregone concepts and does not incorporate recent achievements in solar physics that enable a significantly more advanced understanding. Most semi-empirical models are based on 1D representations of the solar atmosphere that were developed more than two decades ago, and thus do not include current high-resolution solar data and reliable MHD simulations. Since these representations depend on a number of free parameters, semi-empirical models do not unambiguously constrain solar-irradiance variability.

This became particularly conspicuous when data from the Solar Irradiance Monitor (SIM) on the Solar Radiation and Climate Experiment (SORCE) suggested a solar-cycle pattern of irradiance variability completely different from that yielded by empirical and semi-empirical models as well as by preceding observations. While it is now believed that those SIM results are due to high instrumental uncertainties on these longer timescales, the intense discussion and controversy prompted by these data revealed significant gaps in the present understanding of the causes of solar-irradiance variability. Furthermore, recent debate on the historical solar forcing recommendation for the Coupled Model Intercomparison Project Phase 6 (CMIP6) to be used in the upcoming International Panel on Climate Change (IPCC-6) assessment showed that these gaps hinder the progress in modeling of the Sun-Earth connection by potentially misleading climate researchers.

Benefitting from the enormous recent progress in solar observations and models, it is now possible to develop a third generation of irradiance models based on the current state-of-the-art in solar physics. In particular:

- 3D magneto-hydrodynamic (MHD) simulations of flows and magnetic fields in the near-surface layers of the Sun and stars have reached a high level of realism, and can now reproduce many sensitive observational tests. These simulations make it possible to replace 1D representations of the solar atmosphere with realistic 3D simulations and also enable assessment of the contributions of granulation to short-term solar-irradiance variability.

- New time-efficient radiative transfer codes and approaches have been developed. These allow calculated emergent spectra from 3D MHD cubes to account for effects from millions of atomic and molecular lines as well as deviations from local thermodynamic equilibrium, giving more accurate estimates of outgoing radiation as a function of position on the solar disk.

- New atomic and molecular data allow more reliable computation of the opacities in the solar atmosphere. The irradiance variability in the UV, violet, blue, and green spectral domains is fully controlled by millions of Fraunhofer lines. Recent advances in laboratory astrophysics and in consolidating data (e.g. a major upgrade of the Vienna atomic line database, which now also includes molecular data) make possible significantly more accurate calculations of solar-irradiance variability.

- Surface flux transport models (SFTMs) now more realistically simulate the evolution of the large-scale surface magnetic field over the solar cycle. This allows reconstructing the evolution of the solar surface magnetic field and irradiance over long timescales, which is crucial to understanding the pre-anthropogenic solar contributions to climate change from which natural sensitivities of climate can best be determined.

- The magnetic features on the solar surface, which are the main driver of solar-irradiance variability, can now be directly studied with high-resolution imagery from recent solar missions such as the Solar Dynamics Observatory (SDO), STEREO, SUNRISE, HINODE, etc. SDO in particular provides frequent space-based magnetograms, which are needed inputs to the newest physics-based solar-irradiance models.

The incorporation of the aforementioned solar modeling and measurement improvements into irradiance models will provide more reliable and self-consistent solar-irradiance records to the climate community. These physics-based models are also more straightforward to extrapolate to other Sun-like stars and will thus provide a more direct link to and understanding of stellar variability. In particular, these improved models will help distinguish typical photometric signatures of intrinsic stellar variations from exoplanet transits. The interest in this topic has been recently raised to a new level by the CoRoT and Kepler space missions, and with anticipation of the upcoming NASA TESS and ESA PLATO missions.

The challenge to incorporate recent advances in solar physics into this next generation of irradiance models requires communication and collaboration between the irradiance community and researchers working in the fields of solar and stellar MHD simulations, radiative transfer, and surface-flux transport. There have been several successful interdisciplinary meetings aimed at establishing collaborations between the solar-irradiance and Earth-climate communities (e.g., a series of SORCE Science Meetings) and between solar and stellar communities (IAU FM 13 at XXIX GA and IAUS 328). However, few such efforts have been made to link the irradiance community to fundamental physics-based research in solar/stellar atmospheres, which now enable the next generation of irradiance-variability models.

What is needed are international forums attracting researchers spanning the necessary expertise from irradiance and climate models to the physics of stellar and solar atmospheres and magnetic-activity evolution. The IAU provides such a forum. IAU General Assemblies are broadly attended by experts in solar/stellar atmospheres as well as MHD and radiative transfer modelers. The proposed Focus Meeting at the upcoming XXX GA provides a timely opportunity to bring together these experts to discuss recent advances in their individual fields and means of incorporating those advances into the irradiance models.

The IAU Commission E1 Working Group "Solar Irradiance" (http://www.mps.mpg.de/4492376/wg) has recently been created. This group brings together solar-irradiance modelers and observers with experts in MHD simulations, solar magnetic fields, and radiative transfer. One of the goals of the WG is to establish an active collaboration between various communities. The WG is actively involved in outreach activities and recently established a newsletter to keep the community updated on progress. This proposal originates from the WG with its co-chairs acting as SOC co-chairs and WG members acting as SOC Members. In addition to the WG members themselves, the SOC is also strengthened by: Mark Giampapa, who brings expertise in solar-stellar connections; Jie Jiang, who is an expert in solar flux transport models; and Aline Vidotto, who studies interactions of exoplanets with host stars.

This Focus Meeting is coordinated by Division E's Commission E1 (Solar Radiation and Structure), but has strong connections across the IAU. Including the coordinating Division E (Sun and Heliosphere), this meeting is supported by three IAU Divisions. Division G (Stars and Stellar Physics) supports this meeting for the advances it brings to understanding stellar variability. Division B (Facilities, Technologies and Data Science) supports it for the radiative transfer and MHD applicability to solar/stellar modeling that overlap particularly with their Commissions B1 (Computational Astrophysics) and B5 (Laboratory Astrophysics). In addition to being supported by IAU Divisions E, B, and G, this Focus Meeting is supported by six individual Commissions, including all three Division E Commissions, and two Working Groups, one of which is an inter-division Working Group. Letters of support from each are included.

After the proposed Focus Meeting, the Commission E1 WG "Solar Irradiance" will publish a summary of the recent improvements in understandings of solar atmospheric and magnetic-field evolution and dynamics and how those lead to physics-based improvements in solar-irradiance models benefitting the stellar-variability and Earth-climate communities.

Program Outline

The Focus Meeting's two-day agenda is based on carefully selected invited speakers for each of the four planned sessions. Several young speakers will help initiate new collaborations in this multi-disciplinary field. The meeting starts by reviewing the current knowledge of solar irradiance observations and models and proceeds with discussions on recent improvements in understanding the physics of solar/stellar atmospheres, MHD, and radiative transfer. Initial attempts to create new physics-based irradiance models and the synergistic benefits from studies of stellar variability will be discussed, and the benefits these improved irradiance models can offer the climate community will be presented.

Session 1: Available Solar Irradiance Data and Models
- Solar Irradiance Datasets – Will Ball (Switzerland, junior, male)
- Empirical Models Of Solar Irradiance Variability - Odele Coddington (United States, junior, female)
- Semi-Empirical Models of Solar Irradiance Variability – Sami Solanki (Germany, male)
- Long-Term Evolution of Solar Activity – José Vaquero (Spain, male), Hiroko Miyahar (Japan, female)
- Solar Irradiance for Climate Modelers - Joanna Haigh (United Kingdom, female), Amanda Haycock (United Kingdom, junior, female)

Session 2: Structure and Evolution of Solar Surface Magnetic Fields
- Flux Transport Dynamo Models – Emre Isik (Turkey, male)
- Forecasting the Solar Cycle Based On Meridional Flows – Mausumi Dikpati (United States, female)
- Numerical Simulations of the Solar Dynamo – Hideyuki Hotta (Japan, junior, male)
- Magnetoconvection and Flux Emergence – Matthias Rempel (United Sates, male)

Session 3: The Brightness Contrasts of Solar Surface Magnetic Features (Data and Modeling)
- Non-LTE Line Formation in the Solar Atmosphere – Ivan Hubeny (United States, male)
- Atomic and Molecular Data for Radiative Transfer Calculations – Tatiana Ryabchikova (Russia, female)
- Brightness Contrasts of Magnetic Features from High-Resolution Solar Imagery – Fatima Kahil (Germany, junior, female)
- Solar-Irradiance Models Based on 3D MHD Simulations – Serena Criscuoli (United States, female), Kok Leng Yeo (Germany, junior, male)

Session 4: Extrapolating Solar Models to Sun-Like Stars
- Models of Stellar Atmospheres – Fiorella Castelli (Italy, female)
- Facular Contrasts in Sun-Like Stars – Charlotte Norris (United Kingdom, junior, female)
- Extrapolating Solar Models to Estimate Earth-Like Planet Detection Capabilities – Anne-Marie Lagrange (France, female)
- Solar and Stellar Dynamos: Challenges from the Kepler Data – Travis Metcalfe (United States, male), Ricky Egeland (United States, junior, male)